laid upon the importance of the work of G. I. Taylor [1] in eddy-motion in the atmosphere, and of the value of his coefficient of "eddy conductivity" in meteorological work. Frequent references are made to the work of Dines and Dobson with pilot balloons. In the concluding chapters he deals with the "revolving fluid of the atmosphere." The Meteorological Office has published [2] Sir Napier Shaw's previous work along this line, so that the material presented in the latter portion of the "manual" is a résumé of that to be found in the memoir.[3] —*C. L. M.*

THE TRAVELING CYCLONE.

By the late LORD RAYLEIGH.

(The London, Edinburgh, and Dublin, Phil. Mag., and Jour. of Sci., 6th Ser., No. 225, September, 1919, pp. 420–424.)

One of the most important questions in meteorology is the constitution of the traveling cyclone, for cyclones usually travel. Sir N. Shaw [4] says that "a velocity of 20 meters/second (44 miles per hour) for the center of a cyclonic depression is large but not unknown; a velocity of less than 10 meters/second may be regarded as smaller than the average. A tropical revolving storm usually travels at about 4 meters/second." He treats in detail the comparatively simple case where the motion (relative to the ground) is that of a solid body, whether a simple rotation, or such a rotation combined with a uniform translation; and he draws important conclusions which must find approximate application to traveling cyclones in general. One objection to regarding this case as typical is that, unless the rotating area is infinite, a discontinuity is involved at the distance from the center where it terminates. A more general treatment is desirable, which shall allow us to suppose a gradual falling off of rotation as the distance from the center increases; and I propose to take up the general problem in two dimensions, starting from the usual Eulerian equations as referred to uniformly rotating axes.[5]

Sir J. Larmor has added to Rayleigh's incomplete article a paraphrase, which closes as follows: "In any case, internal viscosity is negligible in meteorological problems. It is the friction against land or ocean, introducing turbulence which spreads upward, that disturbs and ultimately destroys the cyclonic system; and the high degree of permanence of the type of motion seems to permit that also to be left out of account. As remarked in the postscript, the changes of pressure arising from convection involve changes of density, which will modify the motion but perhaps slightly. There does not seem to be definite discordance with Dr. Jeffreys's detailed discussion."

ON TRAVELING ATMOSPHERIC DISTURBANCES.[6]

By HAROLD JEFFREYS.

[Author's summary.]

The geostrophic [7] relation between the wind and the surface pressure gradients is incapable of accounting for any variation whatever with time in the pressure distribution. All changes in this arise from those terms in the equations of motion that are neglected when the geostrophic relation is assumed. When these terms, which depend on the squares and differential coefficients of the velocities, are taken into account, it is found that an asymmetrical cyclone can move. It seems, however, from the low speed of travel of these depressions, that a simple superposition of a general pressure gradient on a rotating system must be compensated internally in some way, so as to reduce the asymmetry introduced. Thus the remarkable circularity of the isobars in a cyclone is seen to be a condition of its slow movement. It is indicated that the cyclone itself is a very special type of disturbance, in which the pressure, temperature, and velocity are so distributed as to make the wave tending to readjust it travel with extreme slowness; other types of disturbance spread out much more rapidly (with velocities of the order of that of sound) and are dissipated, and this fact is probably the reason why, [that] of all the irregularities possible, the cyclone is the most conspicuous, other forms dissipating before they can be observed.

[1] Eddy Motion in the Atmosphere, *Phil. Trans.*, 1915, vol. 215, pp. 1–26.
Skin Friction of the Wind on the Earth's Surface, *Proc. Roy. Soc.* Ser. A, 1916, vol. 92, pp. 196–199.
Phenomena Connected with Turbulence in the Lower Atmosphere, idem. 1918, vol. 94, pp. 137–155.
A discussion of these papers by Mr. Eric R. Miller will appear in the October issue of the REVIEW.

[2] Sir Napier Shaw: The Travel of Circular Depressions and Tornadoes and the Relation of Pressure to Wind for Circular Isobars Met. Off. *Geophysical Memoirs*, No. 12-1918.

[3] See Review, p. 643, above.

[4] Manual of Meteorology, Part iv, p. 121, Cambridge, 1919.

[5] Lamb's 'Hydrodynamics, par. 207, 1916.

[6] Phil. Mag., London, January, 1919, Ser. 6, **37**: 1-8. See also Sci. Abs. March, 1919, pp. 92–93.

[7] *Geostrophic.*—"Let us call the one [component] due to the rotation of the earth the 'geostrophic' component, and the other due to the curvature of the path the 'cyclostrophic' component."—Gr. Brit. Met. Office, handbook, Weather Map and Glossary, London, 1918, p. 125.

CHARACTERISTICS OF THE FREE ATMOSPHERE.[1]

By W. H. DINES, F. R. S.

(Abstract.)

SYNOPSIS.—"This report was prepared in 1916, but on account of the war it was not then published." The subject is discussed under the following headings:

1. Methods and places of observation.
2. Amount and reliability of the material.
3. Mean temperatures and gradients.
4. The seasonal variation.
5. The daily temperature range.
6. The humidity.
7. The troposphere and stratosphere.
8. Pressure and density.
9. The motion of the free atmosphere.
10. Statistical data.
11. The connection between pressure and temperature.
12. The vertical temperature gradient and the value of H_a.

Appendix. The standard deviations of the density of the air from 1 to 13 kilometers, and the frequency of occurrence of deviations of given magnitude.

In general the paper deals with data and conclusions that had already been presented elsewhere, but they are here brought together into concise form, together with some of the more recent results. The reader is thus enabled to gain a comprehensive idea of the whole subject without having to consult several separate papers that have appeared from time to time in various publications.

1. *Methods and places of observation.*—For the most part the discussion is based upon results obtained in different parts of Europe, although equatorial and Canadian values are given in some of the tables and are briefly referred to in the text. In all cases the data were obtained by means of sounding and pilot balloons.

2. *Amount and reliability of the material.*—Practically 90 per cent of the balloons sent up in continental Europe are recovered; but in England, owing to the proximity of the sea, the loss averages about 35 per cent. Different sizes of balloons and various types of meteorographs are used, but the mean results of 10 years' work are practically identical. Instrumental and reduction errors are evidently not large, inasmuch as the agreement between near-by stations and between successive observations at the same station is close. All the evidence indicates that the probable error for temperature does not exceed 1° C.; for pressure it is about 4 mb. The effect of the latter in the determination of altitude in the lower levels is inappreciable, but at great heights, e.g., 20 kilometers, an error of 2 kilometers is possible. These errors are largely

[1] Geophysical Memoirs No. 13, Meteorological Office, London, 1919, M. O. 220c, pp. 47-76.